period of the year. On the Pacific slope the rainfall was slightly above the normal; on the Atlantic slope heavy showers caused inundations at several places; at Cariblanco, toward the headwaters of the Sarapiqui River, the amount of rainfall was 1,326 millimeters, which is the greatest monthly amount ever recorded at a Costa Rican station.

Notes on earthquakes.—November 1, 6^h 34^m a. m., light shock, NNW–SSE, intensity II, duration 8 seconds. November 2, 5^h 06^m a. m., light shock, NNW–SSE, intensity II, duration 6 seconds. November 5, 7^h 10^m a. m., very light tremors.

TABLE 2.

Time.	Sunshine.		Temperature of the soil at depth of—					Cloudiness observed, 1901.
	Observed, 1901.	Normal, 1889–1900.	0.15 *m*.	0.30 *m*.	0.60 *m*.	1.20 *m*.	3.00 *m*.	
	Hours.	*Hours.*	° *C*.	° *C*.	° *C*.	° *C*.	° *C*.	%
7 a.m.	2.50	4.81	19.60	19.52	20.74	21.26	21.40	66
8 a.m.	11.41	16.82	......	......	......	......	......	......
9 a.m.	13.42	19.65	......	......	......	......	......	......
10 a.m.	11.01	18.29	19.[illegible]8	19.88	20.77	21.25	......	79
11 a.m.	9.08	16.69	......	......	......	......	......	......
12 m.	9.88	14.84	......	......	......	......	......	......
1 p.m.	8.91	13.40	20.08	20.02	20.83	21.29	......	80
2 p.m.	10.18	13.88	......	......	......	......	......	......
3 p.m.	7.31	12.11	......	......	......	......	......	......
4 p.m.	6.00	9.27	20.10	20.02	20.76	21.23	......	88
5 p.m.	2.64	4.68	......	......	......	......	......	......
6 p.m.	0.17	0.71	......	......	......	......	......	......
7 p.m.	......	......	20.09	20.08	20.71	21.22	......	78
8 p.m.	......	......	......	......	......	......	......	......
9 p.m.	......	......	......	......	......	......	......	......
10 p.m.	......	......	19.99	20.01	20.75	21.22	......	72
11 p.m.	......	......	......	......	......	......	......	......
Midnight	......	......	......	......	......	......	......	......
Mean	......	......	19.96	19.98	20.77	21.24	21.40	78
Total	92.46	144.15	......	......	......	......	......	......

TABLE 3.—*Rainfall at stations in Costa Rica, November*, 1901.

Stations.	Amount.	No. rainy days.	Stations.	Amount.	No. rainy days.
	Mm			*Mm.*	
1. Sipurio (Talamanca)	238	26	14. Juan Vinas	337	22
2. Boca Banano	483	23	15. Santiago	396	27
3. Limon	258	19	16 Paraiso	172	15
4. Swamp Mouth	590	5	17. Las Concavas	219	20
5. Zent	385	17	18. Cartago	193	17
6. Gute Hoffnung*	*	*	19. Tres Rios	204	15
7. Siquirres	567	20	20. S. Francisco G	179	17
8. Guapiles	662	28	21. San Jose	183	18
9. Sarapiqui	1,326	27	22. La Verbena	461	14
10. San Carlos	545	21	23. Nuestro Amo	118	11
11. Las Lomas	604	18	24. Alajuela	210	11
12. Peralta	372	19	25. San Isidro Alajuela	271	16
13. Turrialba	329	19	26. Cachi	194	15

*Not received.

THE REDUCTION OF RECORDS OF RAIN GAGES.

By Prof. MARK S. W. JEFFERSON, State Normal College, Ypsilanti, Mich., dated December 4, 1901.

The time has come to apply corrections to readings of rain gages before entering the figures on maps or tables that are meant to give information about the distribution of actual rainfall. The work of determining these corrections should be given to men of special training in meteorology, with time for the work and abundant data of such sort as have been hitherto collected.

The mere accumulation of rain gage readings is no longer acceptable to students. Additional observations ought to give greater and greater accuracy to our knowledge, and this is not true of lengthening series of observations in which large and varying errors have been allowed to remain.

We must look to Government bureaus for systematic quantitative studies and to students who have ready access to large libraries for their elaboration and the development of statements of law.

The fact that rain catch diminishes in some proportion to strength of wind is quite certain and it now only remains to apply such empirical corrections as the very interesting one suggested on page 182 of the Editor's paper[1] on "The determination of the true amount of precipitation." It would seem to be proper to apply that formula, as he suggests, to all the individual rains of a locality, to see if there is the expected elimination of local and annual discordances.

There must be abundant data in the office of the Weather Bureau for such investigations, and the prevalent use of city house tops as gage stations would seem to demand the application of corrections. I hope some further studies will be made.

I believe a more serious defect in published rainfall data is connected with the principle involved in atmospheric precipitation in general, i. e., that hill precipitation must tend to exceed that of neighboring lowlands. Of course all the officials of the Bureau are perfectly familiar with this fact, but the publications of the Bureau do not show that it is properly kept in mind. Maps should not be labeled normal annual precipitation if they represent merely low gage collections. A geographer must distinguish mountain masses by deeper shades on a rainfall map, whether gages have ever been set up on their summits or not, since never has a mountain been gaged without yielding greater rainfall than the valleys.

Mr. Gannett drew a rainfall map for Mr. Newell's "Results of stream measurements," Fourteenth Annual Report United States Geological Survey, 1892–93, p. 152, which looks far more satisfactory in this respect than the Mean Annual Precipitation Map in the Report of the Chief of the Weather Bureau, 1896–97, p. 320. Mr. Gannett's data were obtained from the Weather Bureau, and perhaps the Bureau's maps of the same date were better than the later ones. This superiority I find on Mr. Gannett's map, in spite of its smallness, in the representation of the precipitation of the Adirondacks and the White Mountains; it also shows the influence of topography in Oregon, Washington, and Colorado. If the later map (1896–97) is to be believed, subsequent observations must have shown Gannett's map to be in error.

We are not limited to rain gages for our knowledge of rainfall. Table V, on page 358 in the Weather Bureau Report for 1896–97 above referred to, gives figures for eleven New England stations which may be supposed to represent the data from which the map is constructed. Now these stations are at elevations varying between 11 and 850 feet, an average of 175 feet above the level of the sea. It is at once clear that this is far below the average elevation of New England, and must represent considerably less than the average rainfall. On page 359 we find the statement—

> While the mountain system of New England does not greatly modify the rainfall conditions, it plays an important part in the water supply of the towns and cities that cluster along the larger rivers. Virgin forest covers in great part the mountain slopes over a considerable area, thus conserving to a certain extent the rains of summer and the snows of winter.

The rainfall conditions referred to are plainly those of the valleys, and only the low valleys at that. The propriety of assuming these low valleys as typical of New England is evident in one sense only, that of being the seat of population. For agriculture and forest growth the mountains do greatly modify rainfall conditions, since if the mountains were not there the rainfall would be very much less. On the next page we learn that Mount Washington has 83.5 inches, with "some uncertainty attached to these figures owing to the well known difficulties experienced in measuring precipita-

[1] Extract from Bulletin No. 7, Forestry Division, United States Department of Agriculture. See also MONTHLY WEATHER REVIEW, October, 1899, Vol. XXVII, p. 464.

tion on mountain tops." This means that it is probably more than 83.5 inches, and considerably more since the wind velocity is very great. Mount Killington, Vt., has measures suggesting over 55 inches annually. It would seem that the average elevation should be determined, and by a comparison of such gage readings as are obtainable the probable values of rainfall be estimated. Such an estimate would be far more accurate and scientific than the customary presentation of figures that are inapplicable to the facts. This is the St. Kitts-Antigua story over again. The gages may say that their precipitation is the same but the statements need qualification. Another case of this neglect of the influence of geography occurs on page 339 of the same report.

The rainfall in the narrow gorge where the Columbia River breaks through the Cascade Range is also heavy, but this is undoubtedly due to local causes. A similar case of very heavy precipitation at a single isolated station is that of Glenora, on the summit of the Coast Range, in Tillamook County, about 30 miles from the ocean. At this place the annual fall in 1896 was 169 inches, probably the greatest rainfall ever recorded in the United States in a single year.

It would seem clear from these two cases that the crest of the range has a very great precipitation, as was to be expected, and at the only two points in the line of the crest where gages are located this large value is measured. The gages may be isolated but the areas are probably continuous along the summit of the range. The causes are of world-wide application.

The maps of the rainfall of India and of Austro-Hungary show almost perfect reproduction of the topography, and I believe that our knowledge of rainfall everywhere will lead us toward similar results as it becomes more perfect.

Dr. B. A. Gould selected Cordoba, Argentina, for his astronomical observatory on the strength of its small rainfall. But to his disappointment the near presence of a mountain range gave Cordoba a cloudiness out of proportion to this rainfall. The city's existence depends on the river (Rio Primero) which is so entirely dependent on the considerable rainfall in the mountains that it disappears in the sand a little farther east. There is a fringe of country all about these mountains watered by streams from the range which are soon lost in the plains. The climatic conditions of this fringe of country are not adequately represented by a statement of local rainfall only. Nor is the increased amount of rainfall on the fringe all that is due to the influence of the presence of the mountains. The moisture content of the ground is immensely important, and is directly increased by a mountain rainfall in the neighborhood.

The association of forests with mountains has not been sufficiently dwelt upon, yet it is well known that mountains are typically forest clad. The Black Hills and Black Forest are commonly cited as referring to this association by their very names. Homer refers to the mountains whenever he wishes to speak of trees, and Virgil's regular phrase for speaking of the forest is *in montibus*, which is perfectly matched in modern Spanish by the word *monte* which regularly now means *woods* and *not* hills. Jorge Isaacs, in the United States of Colombia, calls the forest "La Montaña." And these forests are there because of rain.

I am much interested in stream run off and vegetative transpiration and evaporation at present. Real knowledge of rainfall is necessary to these studies. Two lines of advance seem open.

(1) The modification of existing rainfall data by such correction for elevation above ground, and wind force at the mouth of the gage as may be now applied.

(2) The preparation of self-registering gages that may facilitate mountain observations by requiring only occasional visits by the observer.

Possibly some help may be had indirectly by comparing the run off in inches of the Cochichuate and Mystic Lake watersheds with that of the Merrimac for the same period, as the small areas of the former are wholly on low levels, while the Merrimac has mountain sources for much of its water. Yet it is likely that direct evaporation is considerably less on the mountain slopes than on the lower ground.

This communication is dictated by my desire to urge meteorologists to pay more attention to modifying influences, like the effect of wind or elevation on rainfall. I wish we could have something better than mean annual rainfall statements in fractions of an inch that are without meaning. The units are unreliable enough under present methods. We are getting gage readings under the name of precipitation, and shall do no better until a systematic correction of known errors is applied and, at least, a partial meteorological exploration of mountain slopes is attempted. But even now we know something about mountain rainfall, and this knowledge should be utilized in drawing precipitation maps, even if in part it be drawn from other sources than a rain gage. Let us not pretend that the White Mountains have become drier because we have now no record of their summit rainfall.

I wish that Congress might authorize the Weather Bureau to investigate this matter thoroughly, as its practical importance is very great.

REMARKS ON THE FOREGOING.

By Alfred J. Henry, Professor of Meteorology, in charge of Records Division.

The exposure of the rain gages at the larger Weather Bureau stations is not always as good as might be desired, but it is the best that can be had under the circumstances. The application of a correction to the gage readings before entering them on the records, as suggested by Professor Jefferson, is not considered advisable. Indeed, it is doubtful whether it would ever be advisable to apply corrections to rain gage readings, since such action would involve a determination of the error of each individual gage. The magnitude of this undertaking is readily perceived when we stop to consider that no two roof-exposed gages are identical in their immediate surroundings. In the end the corrected readings would doubtless still be unsatisfactory; it would be much better therefore, both as regards economy of time and labor, to seek a correct exposure at once rather than to attempt to adjust the defective readings. For the forecast work of the Bureau the present gage readings are satisfactory, but for climatic and hydrographic studies more accurate measures of precipitation would be desirable.

The Weather Bureau is no longer dependent, for its climatic work, upon the records of rainfall made on house tops in the large cities. The Climate and Crop Services in the several States and Territories receive monthly reports of rainfall from a large number of stations located mainly in small towns, villages, and on farms. The great majority of the gages at these stations have ground exposures. Moreover, each section director is expected to visit stations in his district and correct faulty exposures when such are suspected to exist.

The concluding part of Professor Jefferson's article is devoted to a criticism of the apparent neglect by the officials of the Bureau of the influence of topography in constructing rainfall maps. He invites attention to a rainfall map prepared by Mr. Henry Gannett, and published in the Annual Report of the United States Geological Survey, 1892–93, and compares it with a map published in the Report of the Chief of the Weather Bureau, 1896–97. The comparison is hardly a fair one, since the last-named map was prepared on a scale altogether too small to admit of distinguishing the higher precipitation of mountain slopes from that of the lowlands.

The purpose of the map published by the Weather Bureau was to show at a glance the broader features of rainfall distribution only, and this it does fairly well.

There is something to be said both for and against the shading of rainfall maps to indicate heavy precipitation on mountain slopes where no actual measurements have been made. That precipitation increases on mountain slopes up to about 4,000 feet elevation is generally admitted, but what the law of distribution is above that level has not been determined for the mountain regions of the far west. The quantity of rain that falls on a mountain slope is not solely a question of elevation. The angle of incidence that the mountain slope makes with the rain-bearing winds is of much more importance than the absolute elevation. The principle enunciated by Professor Jefferson, viz, that hill precipitation must tend to exceed that of neighboring lowlands, has little, if any, *practical application* in the construction of normal rainfall maps where small differences in elevation are concerned. Let us look for a moment at a few records of hill and valley precipitation, taken from the last published annual report of the New England Climate and Crop Service, viz, that for 1900, page 7. The highest point in Massachusetts at which rainfall observations were made in that year was Pittsfield, in the Berkshire Hills, elevation 1,038 feet. The total annual amount was 46.4 inches. At Williamstown, in the same county, but about 300 feet lower, the total annual precipitation was 46.9 inches, substantially the same as at Pittsfield. Worcester, in the same county, but 500 feet lower than Pittsfield, and 200 feet lower than Williamstown, recorded a total fall of 48.8 inches, an amount greater than either of the hill stations, while Springfield, a valley station, in the same part of the State, with an elevation of 200 feet, gave the largest precipitation of any, viz, 49.8 inches.

In New Hampshire there are three stations with elevations above 1,000 feet. The precipitation at these elevated stations was not so great as at stations much lower. The greatest measured rainfall in the State was at Nashua, Hillsboro County, elevation 125 feet. The same is true of Vermont and Maine, and what is true of a single year is true of other years.

A little reflection will show the folly of attempting to adjust rainfall observations for the supposed influence of elevation in a country of varied topography such as New England.

A final word as to the charge of "neglect of the influence of geography," on page 329, quoted by Professor Jefferson. First as to the facts: The record of heavy rainfall in the gorge of the Columbia was made at Cascade Locks, elevation about 125 feet, by the United States Engineer Corps. The course of the river at that point is nearly east and west, and there is no obstruction to the flow of the winds up and down the valley. The writer is not prepared to say that the heavy rains at Cascade Locks in the river valley are due to the presence of mountains a few miles away on either side of the river. About 35 miles farther up the valley on the east side of the Cascades the average annual rainfall is but 15.8 inches, as against 79.0 inches at Cascade Locks.

It has developed since the rainfall report was written that Glenora, Oreg., is not on the summit of the Coast Range, but has an elevation of probably 1,500 feet or less. The Coast Range in Tillamook County does not, according to the contour maps of the United States Geological Survey attain elevations above 2,000 feet except over small areas.

Additional rainfall stations have been established in Tillamook County within recent years. These all show a very heavy precipitation; thus, Bay City on the east shore of Tillamook Bay (sea level) for the four years, 1897–1900, gives an annual mean of 124 inches. Nehalem, at the mouth of the river of the same name, gives an annual mean of 115 inches (five years). The mean annual precipitation at Glenora (eight years) is 136 inches. This fact alone does not justify us in assuming a higher average precipitation for the length and breadth of the Coast Range in Oregon. What we need is more rainfall stations on the higher levels.

THE TEMPERATURE OF THE SOIL AND THE SURFACE OF THE GROUND.

By DEWEY A. SEELEY, Observer, Weather Bureau, Chicago, Ill.

The importance of soil temperature in agriculture is due both to the beneficial effects of heat in the seed bed and to the destructive effects of frosts upon growing crops. The process of germination will not begin in most cultivated crops until a temperature of 42° or more has been reached and maximum results are attained when the temperature of the soil reaches 68° or 70°. Heat is also necessary to weaken the forces which hold together the food constituents in the soil before they become available for the use of the plant. Nitrification will not take place with the soil temperature below 40°, and is most vigorous at 98°. Again, the osmotic pressure by which the plant food is taken into the plant and forced through the stem to its farthest branch and leaf, is made more effective by heat. On the other hand low temperatures, and especially frost, often cause incalculable damage to vegetation.

Purely local conditions have such a decided influence upon the temperature near the surface of the ground that the effects are apparent to the most casual observer. A heavy frost often occurs over one portion of ground while another portion in close proximity, but under different influences will be entirely free from frost. The local differences in temperature in clear weather with light winds are sufficient to be sensible to a person passing from place to place, especially over hills and valleys.

With the importance of soil temperature in view, and the influence of local conditions so apparent, a few observations were made to determine approximately the effects of some of these local conditions expressed in degrees Fahrenheit.

The first series of observations was made to determine the amount of variation in temperature due to elevation. A low swale surrounded by hills was chosen. Two minimum thermometers were placed on the bare ground, one at the lowest point in the swale and the other on the hilltop about 15 feet above. All conditions, except the elevation, were made as nearly as possible alike. The minimum temperatures, recorded on six clear, still nights in January, were as follows:

Observations.	Temperature in swale.	Temperature on hilltop.
	°	°
1	13	15
2	9.5	10.5
3	8	10.5
4	11.5	16.5
5	2	6
6	−10	− 9
Average.	5.7	8.2

The average of the six readings taken on the hilltop was 2.5° higher than corresponding temperatures below. This difference is important, especially when frosts are liable to occur. In order to determine the difference between the temperature at the surface of the ground and in the free air above, another thermometer, which had been placed on a wooden frame work 30 feet high on the hilltop, was read simultaneously with the above instruments. The average of the six readings of this thermometer was 14.5°, or 6.3° higher than the average on the hilltop, and 8.8° higher than in the swale.

The effects of air drainage upon the temperature of the soil were found to be very decided. Minimum thermometers were placed on the ground; the first in a low swale without air drainage, the second on low ground at about the same elevation as the first but with very good air drainage, and the third on a hill about fifteen feet above. Readings were made on three nights with the conditions favorable for frost, and the results were as follows: